Technical Proposal

Development of an Environmental
Manual for Coal-fired Power Plants

Submitted to the
Asian Development Bank

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Tata Energy Research Institute
9 Jor Bagh, New Delhi
INDIA

1.0 Introduction

Coal is a widely available energy resource in Asia having the lowest cost amongst commercial fuels. In China, India and countries along the Pacific rim there is already a heavy reliance on coal fired power generation and with growing energy needs in ~~the~~ these countries, coal use for power generation is expected to increase rapidly in the near future.

The combustion of coal gives rise to pollutants that adversely affect human health and environment. The principal pollutants are particulate matter (PM), oxides of sulphur (SO_x) and oxides of nitrogen (NO_x). There are various control technologies available, depending upon the type and the amount of pollutant that needs to be controlled. The design of such technologies depends upon various factors. The type and quality of coal and the combustion system (boiler type, method of firing, level of excess air, etc.) would determine the amount of pollutants generated. The amount of pollutant that would need to be controlled would in turn depend upon the local air quality standards. Knowing the level of pollution control required, a technology could then be selected depending upon the availability of local resources (water, materials, etc.) and financial affordability. Thus, the selection of appropriate pollution control equipment is a complex task and therefore a computerised tool would be extremely helpful for this purpose.

Several packages have been developed that partially address this issue. One such package that comes closest to this objective is the Integrated Air Pollution Control System developed by EPA. It is a computerised simulation model that estimates costs and predicts the performance of SO_2, NO_x and particulate matter emission control systems for coal fired boilers. The model includes conventional and emerging technologies for pre-, in-situ and post combustion emission control. The emission control technologies can be selected in either isolated or in integrated configurations. However, the database is designed more for application in the U.S. with emphasis on U.S. conditions and criteria (vis-a-vis coal types, boiler types, boiler operations, emission standards, decision criteria, etc.) and therefore is of limited use when applied to a developing country of Asia. It is therefore imperative to develop custom designed software for these countries that would include local/regional information on all techno-economic and other relevant parameters that would enable the selection of optimal pollution control technology for coal-fired utilities.

As of 1990, 149294 MW of installed capacity of coal fired power plants exist in the developing countries of Asia, with China having the largest share (90,009 MW), followed by India (40,893 MW), Korea (5782 MW), Hongkong (5340 MW), Taiwan (3955 MW), Indonesia (1730 MW), Thailand (1165 MW), Philippines (405 MW) and Pakistan (15 MW). Coal for these

plants range from anthracite to bituminous to lignite, with the bulk of these plants (those located in China and India) being run on inferior coal.

The software system to be developed would be designed for use in the above countries. The program would be centered around an expert system that would be interfaced with separate area modules for each country, a module for control technologies, a module for economic and financial analysis, and a module for determining the contribution due to a power plant on the ambient air quality levels for the short (episodic) and long term.

Each area module would include the type of coal, the type and sizes of boilers, air quality standards, currency data, geographic location factors, foreign currency limitations, decision criteria, etc. The database would be exhaustive and would include all information required for the selection of an appropriate control system.

The control technologies for SO_x, NO_x and PM would be described in a separate module. The data for each technology will give information on removal efficiency for different coals and boiler types, material flows in the process (for example $CaCO_3$, NH_3, H_2O, etc.), energy consumption, and capital and operating costs.

The economic and financial analysis module would essentially consist of a discounted cashflow model that would permit the evaluation of control strategies on overall emission levels. Additional features will include choice of discount rates and sensitivity analysis. Both, financial and economic prices (wherever possible) will be included.

The air quality module that would determine the ambient air quality levels in the short term (inclusive of episodic conditions) and long term for a given power plant and specified pollution control equipment will be based on the Gaussian Atmospheric Dispersion Model. TERI has developed a computer simulation Gaussian Dispersion Model which predicts the short term and long term pollutant concentrations with reference to the emission source, given the inputs of wind speed, wind direction, source emission rate and atmospheric stability . The model has been used for studying the impact of a thermal power plant located at Bombay on the ambient levels of the city. This model will be adapted and interfaced with the expert system for use here.

Each of these modules will be tied together with an expert system which would permit the selection of the optimal control equipment based on constraints and criteria of that geographic area. The results of these individual programs would be collected and analysed by the expert system, resulting in an appropriate recommendation.

2.0 Description of the Software Program

2.1 Area Modules: As mentioned in the Introduction, each of the concerned developing countries would be represented by an area module that would primarily map the types of coal, methods of coal preparation, type of boilers and their operating practices to the total pollutant (PM, NO_x, SO_x) that will be generated. Additionally, this module would also include information on air quality standards, geographic location factors and foreign currency limitations for the country. A description of how some of these factors affect the selection of appropriate control technology and therefore the need to incorporate them are given below:

Coal: It is a carbonaceous combustible rock containing both organic and inorganic materials. Ranking of coals is on the basis of fixed carbon, volatile matter, ash, moisture and heating value. All coals fall into one of four categories, anthracite, bituminous, sub-bituminous and lignite on the basis of the fixed carbon content. Asian coals tend to be low sulphur (0.5 to 1.0 percent), but high ash.

During combustion, the inorganic fractions in coal produce solid ash, parts of which find their way into the flue gas stream as particulate matter. Since ash contents in Indian and Chinese coal is high, the particulates produced are also high. SO_x are formed through oxidation of sulphur in the coal, the amount emitted being directly

dependent on the sulphur content of the coal. Although, Indian and Chinese coal have low sulphur content, the net emissions from large installations tend to become significant on account of large quantities of coal used which is even more so due to its inferior quality. NO_x is largely independent of the type of fuel, since almost the entire amount generated is due to the reaction of nitrogen and oxygen of the combustion air.

Coal Preparation: Coal cleaning is either through chemical or physical means. Typically coal preparation is via a variety of physical processes based on the greater density of ash compared to coal itself. The functions involved are size reduction, sizing, cleaning, dewatering and drying. Coal preparation lowers the cost of transport and provides benefits of ash and sulphur reduction.

Boiler: Boiler design and its operational practices affect the amount of pollutants generated. The following are some of the factors connected with the design aspects.

Burners: Burners regulate the air/fuel ratio that is being supplied to the boiler depending upon load conditions. If the air/fuel ratio is less, there is a possibility of poor combustion which would mean lowering of boiler efficiency and therefore more coal will be required for the same level of power generation. This would imply an increase in PM and SO_x. However, since combustion temperature would be lower, No_x levels would also be lower.

Composition of Coal: The composition of coal that is fed into the boiler is a very important factor, especially its volatile matter. Lower the volatile matter, lower will be the combustion efficiency.

Boiler operational practices also has an impact on the pollutants. Some of the factors are:

Partial Load Operation: When the unit is operated at partial loads the boiler will not be able to utilise fully the heat carried by the flue gases. This results in higher combustion temperatures and therefore higher NO_x emissions.

Operation of Burner Tilt Mechanism: The burner tilt mechanism in many power stations does not function and therefore has a direct impact on NO_x emissions.

Most Asian utilities use pulverised coal boilers. Pulverised coal firing has the ability to use a wide variety of coal, good variable load response, a lower requirement for excess air resulting in lower fan power consumption and lower carbon loss, higher combustion temperatures and improved thermal efficiency.

The type of boiler also has a bearing on the emissions of PM, SO_x and NO_x. For example, in the fluidized bed combustion a much larger proportion of ash is retained and

withdrawn from the boiler bottom. The SO_x content can also be reduced by adding additives (chemicals) in the boiler bed. Similarly, on account of lower combustion temperatures the NO_x emissions are also lower.

Therefore, the total amount of uncontrolled PM, SO_x and NO_x depends upon the type of coal, its preparation, the type of boiler, the type of burners and on boiler operating practices. All these factors would be used to determine the amount of pollutants generated.

Air Quality Standards: The amount of pollutant that needs to be controlled would depend upon the air quality standards of the region of concern. Air quality standards are of two types namely (a) ambient and (b) emission. Ambient standards limit the allowable concentration of a pollutant in the air surrounding the power plant. These standards are based upon the environmental damage a pollutant can cause to the inhabitants (human, animal and plants) and are generally expressed in micrograms/m^3. Emission standards specify the maximum amount of a given pollutant which is allowed to be released into the atmosphere. These are generally in the form of mass emission per unit time. Wherever applicable, both criteria would be used to determine the level of control required which in turn would be a major decision parameter required for selection of an appropriate pollution control system.

Geographic Location Factors: These are required to translate capital and operating costs of pollution control equipment for the region of concern. There are various factors that result in a change of equipment costs, such as labour, material and equipment, transportation and construction, and other local effects. All these factors will be estimated for each of the countries.

Other factors affecting the selection are foreign currency limitations, non-availability of resources (water, etc.), and the decision criteria.

The area modules would be organised in a database.

2.2 **Technology Module:** This module will be based on various abatement technologies that exist worldwide and those under development (particularly in Germany) (Information from University of Essen) will be included. This would be developed on information supplied by Dr. Ulf Hansen from the Institute of Power Engineering, University of Essen. The Institute of power engineering has almost ten years experience in analysing emission abatement technologies for fossil fired power stations. Following the introduction of new emission standards in the Federal Republic of Germany in 1983 - at the time the most stringent standards in the world - roughly 50,000 MW of electric power plant capacity have been equipped with stack gas cleaning for removal of sulphur and nitrogen oxides. The efficiency and costs have been calculated

both for new units and for retrofitting old ones. The removal of particulates is already well advanced. Since July 1988 all power plants operating in Germany comply with the regulations, and operating experience is accumulating.

The technologies are:

for removal of particulates

- cyclones
- electrostatic precipitators
- filters

for removal of SO_2

- wet scrubbers with and without production of gypsum
- dry sorbent
- active coal absorption

for removal of NO_x

- selective catalytic reduction (SCR)
- non catalytic reduction (NCR)
- primary measures in the combustion process

simultaneous removal of SO_2 and NO_x

fluidized bed combustion (FBC stationary and circulating) with low NO_x generation and in-situ reduction of SO_2.

The data for each technology will give information on

- removal efficiency for different coals and boiler types
- materials flow in the process (e.g. $CaCO_3$, NH_3, H_2O, etc.)
- energy consumption
- capital and operating costs

Both, capital and operating costs would be broken down into its components so that they can be translated to the region of concern with the help of the geographical

location factors described in Section 2.1. This module would also contain equipment cost scaling factors for each technology option so that costs for different capacities can be estimated.

The German data will be evaluated systematically for the application to coal fired power plants in developing countries. Where appropriate, the data base will be expanded to cover the needs of special coal combustion technologies. This module would be organized in a data base.

2.3 **Economic and Financial Analysis Module:** This would essentially consist of a discounted cash flow model for evaluating various control options, for example coal preparation vis-a-vis flue gas pollution control equipment. The first step would entail the translation of the capital and operating costs of a technology option to the region of concern using the geographical location factors from the area module. Next, these costs may need to be scaled to account for capacity differences based on the scaling factors given in the technology module. Other features included here would be the choice of discount rates, sensitivity analysis and the facility to analyse, both, economic and financial analysis.

2.4 **Air Quality Module:** TERI has developed a computer simulation Gaussian Dispersion Model (GPM). This model predicts the short-term and long term pollutant

concentrations with reference to the emission source, given the inputs of wind speed, wind direction, source emission rate and atmospheric stability. Amongst all models which are available The Gaussian Point Source Dispersion Model was chosen as this was found to be most suitable from the point of view of data availability and accuracy required. The GPM is most appropriate for such an impact exercise and includes, both, atmospheric interactions and meteorological factors to a considerable extent.

The salient features included in the model are :

- algorithms are based on Gaussian plume modeling assumptions.
- model predicts the ground level concentrations (GLC), maximum GLC, distance at which maximum GLC occur and distance at which the plume touches the ground.
- model predicts short-term averages, long-term averages (seasonal, annual), long-term 95 percentile maximum and under worst possible atmospheric conditions (fumigation, trapping).
- ASME model is used for estimating dispersion coefficients.
- wind speed at different altitudes is estimated using wind scaling factors.
- model includes correction for stack downwash.

The model will be adapted and interfaced with the expert system.

2.5 **Expert System:** The expert system will be the heart of the software program. Its primary functions will be to -

1. Integrate the various modules (databases and software programs).
2. Use the area specific selection criteria from the above modules to come up with the selection of the appropriate pollution control system.
3. Provide an interactive and intelligent front end for queries and allow users to input and modify weights, etc.

Development of the expert system will be done using LEVEL5 OBJECT/PC expert system shell. This shell is one of the most sophisticated expert system shells and is well suited for this application for the following reasons:

- Database and external programs interfaces exist.
- Multiple methods of knowledge representation like rules, objects, etc. exist.
- Multiple methods of inferencing including backward and forward chaining.
- Permits an easy development of a good Graphical User Interface (GUI).

2.6 **Overall System Design:** The total framework would include all modules tied together within an expert system environment. User interface would be extremely simple. The whole program would be menu driven with minimal key board usage. This would be brought about by using the GUI

standards of Microsoft Windows which LEVEL5 OBJECT/PC supports.

3.0 **Work Team:** The team for this project is as follows:

Dr. R.K. Pachauri	-	Project Coordinator
Dr. D. Luthra	-	Principal Investigator Integrate all sectors. Particular inputs: Air Quality Dispersion module and Economic and Financial analysis module.
Dr. U. Hansen	-	Member Development of Technology Module.
Dr. R.P. Krishnan	-	Member Development of area module: Boiler types and operations vis-a-vis the total amount of pollutants generated.
Mr. P.V. Sridharan	-	Member Development of area module: Coal types and quality.
Mr. L.R. Suri	-	Member Development of area module: Boiler types and operations vis-a-vis the total amount of pollutants generated. Working jointly with Dr. R.P. Krishnan.
Ms M. Damodaran	-	Member Development of Economic and Financial Analysis module (jointly with the PI).
Mr. J. Hasan	-	Member Design and Development of the Expert System.
Mr. S. Kumar	-	Member Developing software programs for the modules and interfacing them with the expert system.

The biodata of the team members along with their tasks are given in the Annexure.

ANNEXURE

1. PROPOSED POSITION : Project Coordinator

2. NAME : Rajendra K. Pachauri

3. DATE OF BIRTH : 20-08-1940

4. NATIONALITY : Indian

5. EDUCATION

Ph.D.	Economics	North Carolina State University, USA
Ph.D.	Industrial Engg.	North Carolina State University, USA
M.S.	Industrial Engg.	North Carolina State University, USA

6. OTHER TRAINING

7. LANGUAGE & DEGREE OF PROFICIENCY :

English - read, write and speak fluently.

Hindi - read, write and speak fluently.

8. MEMBERSHIP OF PROFESSIONAL SOCIETIES

1. Member, World Energy Council (WEC), London, Commission on Energy for Tomorrow's World, August 1990 onwards.

2. Member, Steerling Committee for the Global Warming Assessment Project of the Stockholm Environment Institute, Center for Global Change, University of Marylad, April 1990 onwards.

3. Chairman (1989-90), International Association for Energy Economics (IAEE), Washington, D.C.

4. Member, Governing Council of Asian Energy Institute, 1989 onwards.

5. President (1988), International Association for Energy Economics (IAEE), Washington, D.C.

6. Member, American Economic Association.

7. Member, Honor Society of Phi Kappa Phi.

8. Member, Task Force on Energy Planning and Modelling, United Nations University, Tokyo-1982.

9. Founding Member & Past Chairman (1980-83), Coordinating Committee, Cooperative International Network for Training & Research in Energy Planning (Secretariat: UNESCO, Paris)- 1980-87.

9. COUNTRIES OF WORK EXPERIENCE : India, U.S.A., Canada.

10. EMPLOYMENT RECORD :

From 1981 to date
Working as Director at Tata Energy Research Institute, New Delhi.

From June 6th 1990 to September 5th 1990
Worked as Visiting Fellow at The World Bank, Washington D.C.

From May 1982 to June 1982
Worked as Senior Visiting Fellow at Resource Systems Institute, East-West Centre, Honolulu.

From August 1981 to August 1982
Worked as Visiting Professor, Resource Economics at College of Mineral and Energy Resources, West Virginia University, USA.

From July 1979 to March 1981
Worked as Director, Consulting and Applied Research Division, Administrative Staff College of India, Hyderabad.

From Summer 1976 and Summer 1977
Worked as Visiting Faculty Member at Department of Economics and Business, North Carolina State University, USA.

From June 1975 to June 1979
Worked as Member, Senior Faculty at Administrative Staff College of India, Hyderabad, India.

From August 1984 to May 1975
Worked as Assistant Professor at Department of Economics and Business, North Carolina State UNiversity, USA.

From August 1968 to August 1971
Worked as Works Manager (Engine Division) at Diesel Locomotive Works, Varanasi, India.

From November 1967 to April 1968
Worked on deputation from Government of India to Montreal Locomotive Works, Montreal, Canada.

From August 1965 to November 1967
Worked as Assistant Works Manager at Diesel Locomotive Works, Varanasi and other managerial positions.

DETAILED TASK ASSIGNED	:	RELATED WORK EXPERIENCE
Project Coordinator		1. Extensive research and research management experience at national and international levels, dealing with various energy and environment projects. Considerable policy analysis experience gained through close interaction with Government since 1975. Was Member, Advisory Board on Energy, Government of India (1983-88), reporting directly to the Prime Minister.
CERTIFICATION	:	I, the undersigned, certify that, to the best of my knowledge and belief, this bio-data correctly describes myself, my qualifications and my experience, I understand that any willful mistatement described herein may lead to my disqualification or dismissal, if employed.

SIGNATURE : 

DATE 7th Oct. 1991

Day Month Year

1. PROPOSED POSITION : Principal Investigator

2. NAME : Damyant Luthra

3. DATE OF BIRTH : 27.12.1957

4. NATIONALITY : Indian

5. EDUCATION

Ph.D, Industrial Engg.	University of Windsor, Canada	1988
M.Tech., Systems and Control Engg.	Indian Institute of Technology, Bombay, India	1981
B.E., Eletrical Engg.	University of Nagpur, India	1979

6. OTHER TRAINING :

7. LANGUAGE & DEGREE OF PROFICIENCY : English - read, write and speak fluently.
Hindi - read, write and speak fluently.

8. MEMBERSHIP OF PROFESSIONAL SOCIETIES : Member of Committee for Evaluating the the Environmental Implications of Energy Policy in the 8th Plan for the state of Maharashtra, India.

9. COUNTRIES OF WORK EXPERIENCE : Canada, India

10. EMPLOYMENT RECORD

FROM	TO	EMPLOYER	POSITION HELD AND DESCRIPTION OF DUTIES
Apr. 1989	onwards	Ekta Research Services (own firm)	Consultant: Working on projects with Tata Energy Research Institute in the areas of Energy Environment Interface.
May 1988	Dec 1988	GERAD, University of Montreal	"Professional de recherche": McGill University research group. Job duties included the translation of the techno-economic energy model, developed for the province of Ontario, Canada (Ph. D thesis) to the MARKAL framework to form a multiregional dynamic model with MARKAL-QUEBEC.

Sept 1981 Dec 1988	University of Windsor, Canada	Teaching and Research Assistant. Research job duties included construction of a techno-econo energy model for Ontario, Cana Teaching duties included the areas Operations Research, Decision Analys and Engineering Economics.

11. DETAILED TASKS ASSIGNED

1. Planning and providing inputs to the overall development of the project and integrating all sectors.

2. Adaptation/extension of the TERI air quality modelling system for the framework to be developed here.

3. Development of economic and financial analysis module.

RELATED WORK EXPERIENCE

1. Principal Investigator: Developme of air quality dispersion modell system and using it to study t dispersion of NO_x from the Ta Electric Company Power Plant in Bo

2. Principal Investigator: Risk-Benef Analysis of Large Scale Methods generating electricity. Include the quantification and costing c environmental impacts from therma nuclear and hydropower generation.

3. Deputy Team Leader: Environmenta considerations in Energy Developmen India Country Study (ADB Project) Includes the Integration of enviror mental considerations for thre energy strategies for a twenty yea time horizon.

4. Developed a techno-economic energ planning model for the province o ontario, Canada (Ph.D. thesis) tha included the supply, conversion, transportation and end-use sectors. The model was translated in the MARKAL framework for inter-connectio with MARKAL-QUEBEC for the Energy Mines and Resources Canada.

5. Designed a plant layout system using EXSYS Expert System in conjunctior with external programs in BASIC (University of Windsor).

6. Extensive experience in developing computerised solutions for various applications (involved interfacing custom designed programs with special purpose packages).

12. CERTIFICATION : I, the undersigned, certify that, to the best of my knowledge and belief, this bio-data correctly describes myself, my qualifications and my experience, I understand that any willful mistatement described herein may lead to my disqualification or dismissal, if employed.

SIGNATURE : Damyanti Kuthiala

DATE . 7 (Day) 10 (Month) 1991 (Year)

1. PROPOSED POSITION : Member

2. NAME : Ulf Hansen

3. DATE OF BIRTH : 2.4.1937

4. NATIONALITY : German

5. EDUCATION

Ph.D, Engineering	Technical University, Aachen, Germany	1969
Mechanical Engineering and Nuclear Reactor Engineering	Technical University, Aachen, Germany	1965
Mechanical Engineering	Technical University Graz, Austria.	1958

6. OTHER ACTIVITIES : Visiting lecturer at the IABA International Training Course on Energy Planning in Developing Countries, Argentina 1985.

Guest scientist with the Systems Analysis Group, Riso Research Centre, Denmark 1986.

Visiting lecturer at the European Communities' Teaching Seminar on Energy Planning in the Electricity Sector, India 1988.

Invited lecturer to the Sanderstolen seminars 1989 and 1990, and to the Bergen Energy Conference 1990.

7. LANGUAGE & DEGREE OF PROFICIENCY : Norwegian, English and German. Basis in French and Dutch.

8. MEMBERSHIP OF PROFESSIONAL SOCIETIES : Coordinator of the expert group "Energy Cola Electricity"within the Indo-German governmental agreement on scientific and technical cooperation, New Delhi, Bonn 1991.

Member of the OECD/International Energy Agency review team of CSFR to prepare recommendation and advice on energy energy policy for the Czech Government, 1991.

Member of various advisory bodies to the German Government and the Commission of the European Communities, Brussels.

11. DETAILED TASKS ASSIGNED

Development of technology module (PM, SO_x and NO_x control technologies: data on costs, efficiencies, material requirements, etc.)

: Major Studies on the efficiency and costs of emission abatements, economics of German and European Nuclear Energy Strategy, and the decoupling of economic growth and energy use. Research work has included cogeneration combined cycles, and evaluation of emissions from energy conversion. Particular interest given to energy systems planning and to economic evaluation of energy projects such as electricity generating alternatives. At present, involved in environmental effects of energy systems.

(See employment record)

12. CERTIFICATION

. I, the undersigned, certify that, to the best of my knowledge and belief, this bio-data correctly describes myself, my qualifications and my experience, I understand that any willful mistatement described herein may lead to my disqualification or dismissal, if employed.

SIGNATURE . ULF HANSEN

DATE 7 (Day) 10 (Month) 1991 (Year)

PROPOSED POSITION	:	Member
NAME	:	Radha P. Krishnan
DATE OF BIRTH	:	September 14, 1943
NATIONALITY	:	USA
EDUCATION	:	Ph.D. 1974 (Kansas State University) MS 1970 (University of North Dakota) M.Tech 1968 (Indian Institute of Technology) B. Tech 1966 (University of Madras)
OTHER TRAINING	:	Coal conversion technologies, environmental systems, analysis and modelling (see publications)
LANGUAGE AND DEGREE OF PROFIECIENCY	:	Englgh
MEMBERSHIP OF PROFESSIONAL SOCIETIES	:	American Institute of Chemical Engineers Sigma XI, Phi Lambda Upsilon.
COUNTRIES OF WORK EXPERIENCE	:	US and India.

EMPLOYMENT RECORD

From February 1979 to date
Working as a Development Staff Member, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830, USA.

Projects-

US technical specialist in USAID-India coal projects.

1. Designed and erected a pilot scale sate-of-the art FBC facility at BHEL (first of its kind in India).
2. Prepared a joint design for BHEL for a 30 MW coal-fired FBC utility-boiler.
3. Coal gasification hotand cold gas clean-up system studies with RRL, Hyderabad and BHEL, Hyderabad.
4. Coal beneficiation by the media cyclones-set up and test facility and operated it at CFRI, Dhanbad.
5. Coal-water slurry combustion in FBC's with BHEL< Trichy.
6. Design, erection and commissioning of fuels evaluation test facility for testing Indian coals- BHEL, Trichy.
7. Development of slagging of coal combustors for high-Indian coals pilot scale testing and performance analysis, BHEL, Trichy.
8. Monitoring of NO_x, SO_x and particulates from coal-fired utilities with BHEL, Trichy and CPRI, Bangalore.
9. Environmental assessment of coal cycle with TERI, India.

- Modelling and testing in fluidized bed combustor (FBC) pilot scale systems for design and scale up of FBC utility systems.

- International technology assessment of fluidized bed combustion systems.

- Coal liquid property data needs for design of coal liquefaction reactors and solid-liquid separation systems.

- Indo-US commission representative for coal technology.

- Technology needs for scale-up of coal-liquefaction.

- Slurry pumps and pressure letdown valves.

- Carbon utilization in fluidized bed combustion systems.

- Kinetics of coal combustion.

From September 1976 to January 1979
Worked as a Lecturer and Research Associate, West Virginia University, Morgantown West Virginia, USA.

Projects-

- Hydrodynamics and design of fluidized bed systems.

- Modelling of fluidized bed combustion system.

- Pneumatic transport of a coal-gas slurry.

From October 1974 to August 1976
Worked as an Associate Engineer, Midwest Research Institute, Kansas City, Missouri, USA.

Projects-

- Modelling of water quality of the Missouri river.

- Non-point waste discharge impact assessment.

- Air quality models for fugitive emissions.

- Plume model for air quality near coal-fired power plant.

September 1970 to September 1974
Worked as a Research Associate, Kansas State University.

DETAILED TASK ASSIGNED : RELATED WORK EXPERIENCE

Development of Area module: Boiler types and operations vis-a-vis the total amount of pollutants generated.

See projects listed under Employment Record.

CERTIFICATION : I, the undersigned, certify that, to the best of my knowledge and belief, this bio-data correctly describes myself, my qualifications and my experience, I understand that any willful mistatement described herein may lead to my disqualification or dismissal, if employed.

SIGNATURE : R.P. KRISHNAN

DATE FOR SIGNATURE: 7 (Day) 10 (Month) 1991 (Year)

1. PROPOSED POSITION . Member

2. NAME : P.V. Sridharan

3. DATE OF BIRTH : 20.08.1940

4. NATIONALITY : Indian

5. EDUCATION

Post Graduate Diploma	Management	All India Management Association, New Delhi	1986
First Class Colliery Managers' Certificate		Director General of Mines Safety, Dhanbad, Bihar	1969
Second Class Colliery Managers' Certificate		Director General of Mines Safety, Dhanbad, Bihar	1966
B.Sc. A.I.S.M. Hons)	Mining Engg	Indian School of Mines, Dhanbad, Bihar	1963

6. OTHER TRAINING : General Management Course on coal mines organized by national Coal Board, U.K. (3 months, 1983)

7. LANGUAGE & DEGREE OF PROFICIENCY : English - read, write and speak fluently.

Hindi - read, write and speak fluently.

8. MEMBERSHIP OF PROFESSIONAL SOCIETIES : Indian Institute of Public Administration and all India Management Association.

9. COUNTRIES OF WORK EXPERIENCE : India

10. EMPLOYMENT RECORD

From January 1989 to date
Working as Dean (Energy Policy), at Tata Energy Research Institute, New Delhi.

From July 1986 to December 1988
Worked as Fellow at Tata Energy Research Institute, New Delhi on various projects mainly in the coal sector.

From June 1983 ro June 1986
Worked as Deputy Chief Mining Engineer/Company Secretary at Central Coal Fields Ltd., Ranch, Bihar.

From June 1979 to May 1983
Worked as Supdt. (MInes)/Technical Secretary to CMD at Central Coal Fields Ltd., Ranchi, Bihar.

From September 1975 to July 1979
Worked as Senior Mining Engineer, CMD's Secretariat at Central Coal Fields Ltd., Ranchi, Bihar.

From November 1970 to August 1975
Worked as Colliery Manager in different nationalized and private sector mines.

From January 1966 to October 1970
Worked as Assistant Colliery Manager in different collieies.

11. DETAILED TASKS ASSIGNED : RELATED WORK EXPERIENCE

Development of area module: Coal types and quality for countries concerned.

Extensive experience in the coal sector (see Employment Record for details).

12. CERTIFICATION : I, the undersigned, certify that, to the best of my knowledge and belief, this bio-data correctly describes myself, my qualifications and my experience, I understand that any willful mistatement described herein may lead to my disqualification or dismissal, if employed.

SIGNATURE : M Lodha

DATE FOR SIGNATURE: 7 (Day) 10 (Month) 1991 (Year)

PROPOSED POSITION	:	Member
NAME	:	L.R. Suri
DATE OF BIRTH	:	1st February, 1925
NATIONALITY	:	Indian
EDUCATION	:	B.Sc (Engineering) Electrical & Mechanical Banaras Hindu University
OTHER TRAINING	:	Training in Mechanical hdnling equipments. Training in erection of large thermal power stations.
LANGUAGE AND DEGREE OF PROFIECIENCY	:	Engligh - can speak, red and write fluently. Hindi - can speak, red and write fluently. Russian - can speak, red and write fluently. German - can speak, red and write fluently.
MEMBERSHIP OF PROFESSIONAL SOCIETIES		1. Member, Committee appointed by the Govt. of India on Modernisation of Maintenance Procedures in Large Thermal Power Stations. 2. Member of the Working Group appointed by the Govt. of India to study the Slurry Pipeline Transport of Coal. 3. Member of the Committee appointed by the Govt. of India for technical assessment of the working of the Rajasthan Atomic Power Station. 4. Director, Instrumentation Ltd. Kota. 5. Director, National Thermal Power Corporation Ltd., New Delhi. 6. Member, Central Board of Management for Power Projects (Dept. of Atomic Energy, Govt. of India).
AWARDS	:	Receipient of Central Board and Irrigation and Power Award for outstanding contribution in the field of power engineering. Receipient of Scroll of Honour from Institution of Engineers (India) for outstanding contribution to the progress and advancement of the electrical engineering fraternity.
COUNTRIES OF WORK EXPERIENCE	:	India.

10. EMPLOYMENT RECORD

From May 1985 to date
Working as Secretary General, National Council of Power Utilities.

From February 1984 to April 1985
Worked as Chairman, Haryana State Electricity Board.

From August 1980 to March 1985
Worked as a Member (Operation/Thermal), Central Electricity Authority.

From 13th May 1977 to July 1980
Worked as a Member or any other higher post at Badarpur Thermal Power Station. (General Manager upto 31.3.1978 and Chief Engineer Level-1 from July 1978).

From 7th December 1973 to 12th May, 1977
Worked as a Chief Engineer or equivalent at Badarpur Thermal Power Station (General Superintendent).

From 20th November 1973 to 6th December 1973.
Dy. Chief Engineer or equivalent at Central Electricity Authority, Director - Selectio

From 1st July 1964 to 19th November 1973
Dy. Chief Engineer in Neyveli Lignite Corporation Ltd.

From 1st November 1957 to June 1964
Executive Engineer or equivalent in Central Water and Power Commission, GOI.

From 15th July 1955 to October 1957
Asst. Executive Engineer or equivalent in Central Water and Power Commission, GOI.

From 27th December 1948 to 14th July 1955
Asst. Engineer or equivalent in Central Water and Power Commission, GOI.

11. DETAILED TASK ASSIGNED : RELATED WORK EXPERIENCE

Development of Area module: Boiler types and operations vis-a-vis the total amount of pollutants generated. Working jointly with Dr. R.P. Krishnan.

45 years experience in Investigation, Planning, design engineering, procurement, erection, operation and maintenance of Large Thermal Power and River Valley Projects. See Employment Record for details.

12. CERTIFICATION : I, the undersigned, certify that, to the best of my knowledge and belief, this bio-data correctly describes myself, my qualifications and my experience, I understand that any willful mistatement described herein may lead to my disqualification or dismissal, if employed.

SIGNATURE :
DATE : 7.10.1991

PROPOSED POSITION	:	Member
NAME	:	Mala Damodaran
DATE OF BIRTH	:	24th November, 1965
NATIONALITY	:	Indian
EDUCATION	:	

M.A.	Business Economics	University of Delhi, 1989.
B.A. (Hons.)	Economics	University of Delhi, 1987.

OTHER TRAINING	:	
LANGUAGE AND DEGREE OF PROFIECIENCY	:	English - can speak, red and write fluently. Hindi - can speak, red and write fluently.
MEMBERSHIP OF PROFESSIONAL SOCIETIES	:	
COUNTRIES OF WORK EXPERIENCE	:	India.

. EMPLOYMENT RECORD

From July 1986 to date
Working as Research Associate at Tata Energy Research Institute, New Delhi on various projects in energy and environment.

. DETAILED TASK ASSIGNED	:	RELATED WORK EXPERIENCE
Development of Economic and Financial Analysis module (jointly with the P.I.).		1. Team member: Risk-Benefit Analysis of Large scale methods of generating electricity. Specific tasks included the quantification of environmental impacts from thermal power generation. 2. Team Member: Environmental considerations in Energy Development- India Country Study (ADB project). Tasks include costing and analysis of pollution control equipment.
CERTIFICATION	:	I, the undersigned, certify that, to the best of my knowledge and belief, this bio-data correctly describes myself, my qualifications and my experience, I understand that any willful mistatement described herein may lead to my disqualification or dismissal, if employed.

SIGNATURE : Mala Damodaran

DATE : 7 ·10 1991
Day Month Year

1. PROPOSED POSITION : Member

2. NAME : Javed Hasan

3. DATE OF BIRTH : 15.10.1964

4. NATIONALITY : Indian

5. EDUCATION

Master of Science in Industrial Engineering,	Louisiana State University, Baton Rouge, U.S.A.	1987
Bachelor of Technology, Metallurgical Engineering	Indian Institute of Technology, Kanpur, India	1986

6. AWARDS : National award for excellence for the year 1989-90 by NIIT.

: National merit scholarship 1980 and 1982

7. LANGUAGE & DEGREE OF PROFICIENCY : English - read, write and speak fluently.
Hindi - read, write and speak fluently.
Urdu - read, write and speak.

8. MEMBERSHIP OF PROFESSIONAL SOCIETIES : Inducted as life member of Alpha Pi Me, the Industrial Engineering Honour Society, for overall excellence.

: Member, Institute of Industrial Engineering

9. COUNTRIES OF WORK EXPERIENCE : U.S.A., India

10. EMPLOYMENT RECORD

FROM	TO	EMPLOYER	POSITION HELD AND DESCRIPTION OF DUTIES
April 1991 onwards		National Institute of Informational Technology, New Delhi, India.	CONSULTANT,
April, 1989	March 1991	-do-	Senior Systems Executive
August 1988	March, 1989	-do-	Systems Executive

April, 1988	July, 1988	-do-	Senior Systems Associate Working in the Computer Applications Research Division. Resposnsibilities include Development and Deployment of Expert Systems and new products for NIIT. Work involves identifying, designing and developing expert systems for clients and supporting Expert System shells level5 Object, Level5 and VP-Expert.
Aug, 1986	Dec 1987	Louisiana State University, Baton Rouge, U.S.A.	Graduate Assistant Taught freshman engineering students the basics of Engineering Graphics, and Computer Aided Design.

11. DETAILED TASKS ASSIGNED

Design and development of the Expert System

Projects Completed

1. A project planning Expert System for Engineers India Ltd.
2. A crowd control trainer for National Police Academy, Hyderabad.
3. An expert system for personal tax planning.
4. An intelligent Personnel Manual - Persman.
5. An expert system for troubleshotting and diagnosis of Gleason Coniflex gear cutting mechines for TELCO, Jamshedpur.
6. An Expert system for loan application appraisal for small scale industries.
7. An expert stystem for hierarchial/ relational DBMS design.

Currently supervising

1. An expert system for LPG handling methods for IOCL, Bombay.
2. An expert system for rerouting electricity in case of breakdowns for Calcutta Electric Supply Corporation.
3. An expert system for fault diagnosis of Televisions for Videocon International Ltd.

12. CERTIFICATION : I, the undersigned, certify that, to the best of my knowledge and belief, this bio-data correctly describes myself, my qualifications and my experience, I understand that any willful mistatement described herein may lead to my disqualification or dismissal, if employed.

SIGNATURE : [signature]

DATE FOR SIGNATURE: 6 Th Oct 1991
Day Month Year

1.	PROPOSED POSITION	:	Member
2.	NAME	:	Satish Kumar
3.	DATE OF BIRTH	:	October 5, 1965
4.	NATIONALITY	:	Indian
5.	EDUCATION	:	B.Sc., General, 1985 Delhi University M.Sc., Maths with Computer Science, 1987 Jamia Millia Islamia.
6.	OTHER TRAINING	:	
7.	LANGUAGE & DEGREE OF PROFICIENCY.	:	English & Hindi. Fluent.
8.	MEMBERSHIP OF PROFESSIONAL SOCIETIES	:	Computer Society of India.
9.	COUNTRIES OF WORK EXPERIENCE	:	India.
10.	EMPLOYMENT RECORD	:	
	FROM	:	29th Sept., 1987 TO Presently.
	EMPLOYER	:	Tata Energy Research Institute (TERI), New Delhi.
	POSITION HELD AND DESCRIPTION OF DUTIES	:	Research Associate Software development, Software maintenance, Hardware maintenance, End user training, Desktop publishing, Data processing.
11.	DETAILED TASKS ASSIGNED:		WORK UNDERTAKEN WHICH BEST ILLUSTRATES CAPABILITY TO HANDLE THE TASKS ASSIGNED
	Developing software programes and database for all the modules and interfacing them with the expert system		COMPUTER KNOWLEDGE Languages known : BASIC, COBOL, FORTRAN, PASCAL C, PROLOG. Packages used : DATABASE : dBase III Plus, Clipper SPREADSHEET : Lotus 1-2-3

Computer Worked on :

1) Mainframe - NEC-S-1000
2) Mini - PSI OMNI
3) Micros - PC/XT/AT/386

Operating system worked on :

ACOS-6, PSIX, UNIX, XENIX, MSDOS.

SOFTWARE DEVELOPMENT

Package developed :

1) TERI's Reference Energy System Simulator.
2) User friendly computer program for collector performance prediction.

Package developed & maintained :

1) Payroll system
2) Personnel system
3) Equipment maintenance system
4) Income tax program
5) Health Insurance system

Developing :

1) Energy audit software
2) Tissue culture pilot plant research, production and planning software.

12. CERTIFICATION

I, the undersigned, certify that, to the best of my knowledge and belief, this biodata correctly describes myself, my qualifications and my experience. I understand that any wilful mis-statement described herein may lead to my disqualification or dismissal, if employed.

SIGNATURE

DATE OF SIGNING : 07 / 10 / 91
DAY MONTH YEAR